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CASE STUDY

A basis water quality monitoring plan for rehabilitation and protection

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ABSTRACT

BACKGROUND AND OBJECTIVES: Safeguarding water resources became a major concern in many parts of the world as it aims to provide safe and healthy water for humans. Water quality monitoring is a popular tool in ensuring water quality is safe and within the allowable limits and standards for the health of the community. To provide interventions and strategies for the rehabilitation, a water quality monitoring plan was conducted to describe the water quality and the classification of the river.
METHODS: This study conducted an environmental analysis to determine existing conditions and processes in the surrounding environment such as the land use, drainage pattern, reconnaissance survey of the river, and a key interview to describe the barangay profile and the community's water use and practices. The water quality monitoring covers the evaluation of ten water quality parameters: temperature, pH, dissolved oxygen, total dissolved solids, total suspended solids, phosphate, nitrate, oil and grease, chloride, and E. coli.
FINDINGS: Results of the study presents the water quality against the ten water quality criteria. Phosphate measured on four stations ranges between 2.40-4.50 mg/L exceeding the allowable 0.50mg/L; the oil and grease exceeds the standards 2 mg/L with measured values of 2.40-4.60 mg/L in stations 2, 3, and 4; while measured chloride in all stations prove that the water is salty with values exceeding the freshwater requirement of 250mg/L; and the measured TSS in stations 2, 3 and 4 ranges from 32.30 to 49.3 mg/L exceeds the standards of 30 mg/L. E. coli was also detected in water samples collected in all sampling stations. The computed water quality index of 39.02 described water as poor, always impaired, and threatened by the surrounding environment.
CONCLUSION: The measured concentrations for phosphate, oil/ grease, chloride, and TSS exceeds the water quality requirement suggesting that the water is contaminated. The E. coli detected in all water samples, further recommends prohibition of recreational activities to avoid accidental intakes and skin contact on the polluted water. The existing activities in the surrounding residential, commercial and agricultural areas contributed to water contamination as aggravated by the unreliable drainage system, absence of proper sanitation facilities, and collection and disposal behavior of the community. From this, a scientific basis can be drawn on how the river can be rehabilitated and protected and serve as guide for policymakers and water managers on implementing strategies to achieve sustainable water resources.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
39	**5**	**4**

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INTRODUCTION

Rivers play a significant role in agriculture, human consumption and recreational activities, and industries. But population growth, climate change impacts, industrial processes, transportations emissions, agricultural and industrial wastes, urban runoff (Wei and Yang, 2010; Mohiuddin *et al.*, 2011) physical and chemical processes such as weathering and dissolution of minerals, parent rocks, and soils (Adamu *et al.*, 2011; Skordas *et.al.*, 2015; Purushothaman and Chakrapani, 2007) gradually impact the natural water ecosystem impairing the water quality (Parry *et al.*, 2007; Razzaghmanesh *et al*, 2005). It is therefore important to safeguard the water resources to ensure that water quality conforms within the acceptable limits to protect the water resources and the public health (Said *et al.*, 2004; Neri *et al.* 2012; WHO, 2012). To safeguard water resources, water quality monitoring is designed to determine the physical, chemical, and biological characters of water for human health and consumption (US EPA, 2005). Moreover, water quality monitoring is designed to confirm the water quality suitable for its intended use (Azizi *et al.*, 2016). In addition, monitoring is done to determine the trends in the aquatic environment and describe how the contaminants enter and affect the natural aquatic environment (Bartram and Balance, 1996). Therefore, water quality monitoring has become an important activity in assessing and evaluating the conformity of water for drinking and recreational activities. Taal Lake in Talisay, Batangas, Philippines was declared safe for bathing, swimming, and skin diving, and aquaculture after monitoring and evaluating nine water quality parameters (Martinez and Galera, 2011). Monitoring of Mangonbangon River in Tacloban City, Philippines revealed that the river is unpolluted from the total heavy metal content (Decena *et al.,* 2018). The study conducted on Pasig River, Philippines revealed that the river is very poor and degrading from the presence of stagnant, blackish, and stinking water (Gorme *et al*, 2010). While, the monitoring and assessment of water quality conducted in Buhisan River, Cebu Philippines revealed that the mean midstream and downstream did not conform to class D surface water (Maglangit *et al.*, 2014). More so, the 36 river monitoring stations in Palawan, Philippines using nine parameters and water quality index showed

good to excellent water quality for agriculture, irrigation, and other purposes; while five (5) river monitoring stations showed good to excellent ratings after treatment and suited for class A (Martinico-Perez *et al.*, 2019). Evaluation and assessment of water quality parameters provide direction to a water quality monitoring plan. The ten primary water quality parameters as mandated by the Department of Natural Resources-Environmental Management Bureau is used in this study for the evaluation of the water quality standards of the study area. The sample collection and method of analysis of previous studies were considered and followed to achieve the objectives of the study. To aid the water quality monitoring plan, a popular tool known as Water Quality Index (WQI) was developed. WQI was described as the most effective way to describe the quality of water (Regmi and Mishra, 2016; Akter *et al.*, 2016). With the aid of WQI, descriptions such as generally moderate water quality of Lake Taihu Basin (Wu *et al.*, 2018); good water quality in the upstream and midstream of the Chillan River (Debels *et al.*, 2005), the average water quality of Mantayupan falls at the headwater down the river channel (Neri *et al.*, 2012) and poor water quality of Pasig River in Metro Manila, Philippines (Regmi and Mishra, 2016) were used to describe the general water quality. Since the rating scores of WQI of the Canadian Council of Ministers of Environment provide a simple description of water quality, this study adopted the same methodology for the understanding of the local community. In the Philippines, RA 9275 or the Philippine Clean Water Act of 2004 defines water quality in terms of physical, chemical, biological, or radiological characteristics by which the acceptability of the water is evaluated to conform with Administrative Order: 2016-08 or the Water Quality Guidelines and General Effluents Standards of 2016 (DENR-EMB, 2016). In general, drinking water of good quality should be clear and free of harmful substances and must conform to the Philippine National Standards for Drinking Water. While recreational waters must be free from any contaminants as accidental drinking and skin contact is expected during bathing and swimming. The Department of Environment and Natural Resources identified that almost half of the classified rivers in the country did not meet the minimum standards for beneficial use as impaired by domestic, industrial,

and agricultural sources; and almost 50 out of 427 rivers are considered biologically dead (Cabacungan, 2016). One of the rivers in San Jose, Occidental Mindoro is the Pandurucan River and is believed to be impaired and degrading; however, there is no substantial evidence on the water quality and no scientific study has been carried out to investigate the characteristic of water and the possible sources of contamination. This study aims to present a water quality monitoring plan to provide information on the water quality conditions of Pandurucan River. The river has a plan to be rehabilitated as a tourist destination and the information obtained from this undertaking intends to provide scientific bases to support sound decision-making for San Jose water managers and policymakers. Results of the study can provide significant proof on water quality conditions, sources of contaminants, level of pollution and understand how human activities impaired the natural water ecosystem. Specifically, this study aims to present the physical/chemical and microbial analysis of water; conduct environmental analysis considering all present situations of the surrounding areas; characterize the water quality condition using Water Quality Index; determine the significant differences between water quality at different sites and different seasons; and recommend strategies for water quality management plan of Pandurucan River, San Jose, Occidental Mindoro. The water quality monitoring covers the period of 2019 to 2020.

MATERIALS AND METHODS

Study area

Pandurucan River is located at San Jose, Occidental Mindoro covering San Roque and Labangan Poblacion on its midstream and downstream sections. The river is generally used for recreational purposes as swimming and bathing which are commonly observed and enjoyed. Four sampling stations were selected based on the drainage pattern and probable point sources and the center of commercial and residential areas. Table 1 shows the descriptions of the sampling stations.

Sampling method and data collection

One grab sample was taken every month in the four identified stations from September 2019 to February 2021. Water samples were collected simultaneously on the four sampling sites following the standard procedures recommended by Administrative Order 2016-08. In situ, water

Table 1: Description and profile of sampling station sites (PAG-ASA, 2021)

| Stations	Description
Station 1: Labangan Poblacion	The station is located at 12˚ 21' 55"N 121˚04'36''E at Labangan, San Jose, Occidental Mindoro. It is located in mangrove areas with riverbanks riprapped with nearby salt farm. The station is characterized by clear water during the dry season and muddy water during the wet season while the river bed is covered with pebble stones. Under the Type A climatic conditions, average temperature in the site is 27.96ºC with rainfall amount 113.23 mm. Most of the land cover is agricultural use and generally residential and commercial areas.
Station 2: San Roque	The station is located at 12˚ 21' 54"N 121˚04'00''E of San Roque, San Jose, Occidental Mindoro. At the station is the Pandurucan Bridge with river water characterized by scattered garbage in the river banks and surrounding mangrove. The water is typically greenish to brownish and a foul smell can be observed. The river bed is covered with muddy clay. The station is also covered of Type A climate conditions with average temperature of 28.29ºC and accumulated rainfall amount during the study period of 3,634.90 mm. Most of the land cover surrounding the station is categorized as highly dense residential, residential and commercial areas.
Station 3: Market area	The station can be found in 12˚ 21' 20"N 121˚03'52'' E with visible residential houses, garbage and waste on the riversides, snail shells in the river banks with greenish to brownish water. A foul smell can also be observed. The river bed is also covered with muddy clay. The station is generally surrounded by residential areas and commercial establishments. The rainfall pattern is the same as Station 2 with an average temperature of 28.32ºC.
Station 4: Downstream-outlet	The station is situated at 12˚ 21' 01"N 121˚03'41''E of Brgy 5, San Jose, Occidental Mindoro. The station point is characterized by residential houses with garbage (diapers and plastics); a mass of soil that separates the river and the sea. There are swimming children can be seen, and the river bed is covered with a sandy bottom. The water is bluish during sunny weather. The station is considered as the outlet of the river since it faces an opening to Mindoro Strait. Average temperature in the station is 28.42ºC.
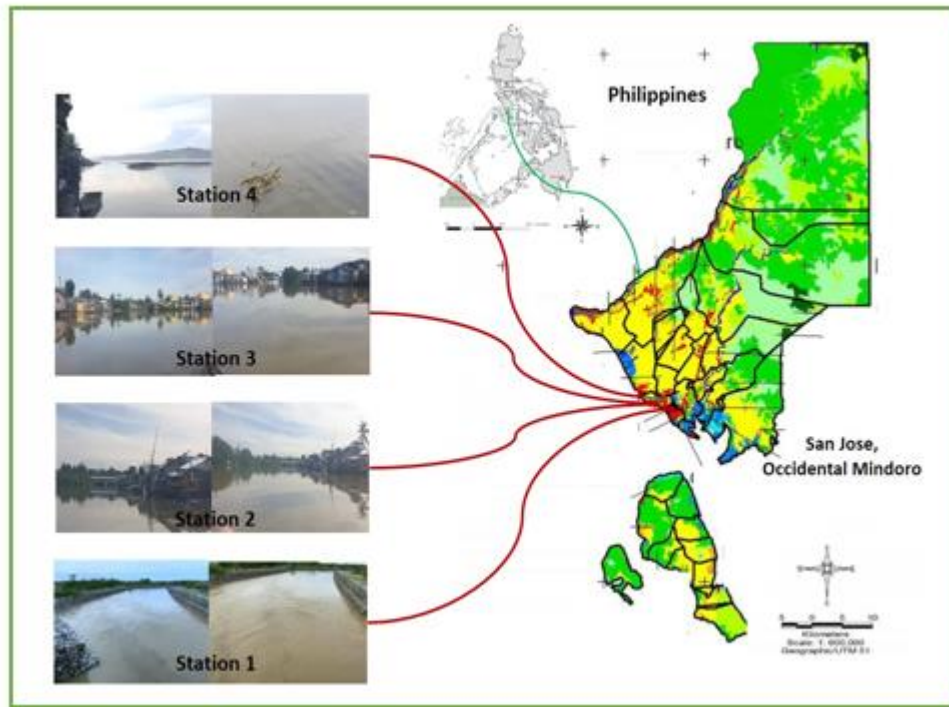
Fig. 1: Geographic location of the study sampling stations at San Jose, Occidental Mindoro, Philippines

quality analyses were done for the temperature, pH, dissolved oxygen, total dissolved solids, and total suspended solids using a multi-parameter probe; while water samples for phosphate, nitrate, chloride were collected and brought for laboratory analysis in Provincial Environmental and Natural Resource Office (ENRO)-Batangas City, Philippines. Samples for E. coli were also brought in ENRO and analyzed using the Multiple Tube Fermentation.

Environmental analysis

Walkthrough analysis was conducted to determine the prevailing conditions in the surrounding environment of the river and to describe the profile of each sampling station. Interviews with the barangay health workers were also conducted to determine the barangay health profile such as population, growth rate, death rate, number of households, and common health problems. A questionnaire with 138 respondents of San Roque and 153 respondents of Labangan was surveyed to determine the water sources and the water use of households.

Water quality index (WQI)

The study adopted the WQI of the Canadian Council of Ministers of Environment. CCME is designed to express water quality information that is easily understood by water managers and the public (CCME, 2001). The calculation of index scores can be obtained using Eq. 1 while, the WQI value for each rank is shown in Table 2.

$$\text{Water Quality Index} = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \qquad (1)$$

Where;

F_1 = percentage of variables that do not meet the objectives

F_2 = percentage of individual tests that do not meet the objectives

F_3 = amount by which the objectives are not meet

Table 2. Water quality objectives used in the model for aquatic ecosystem and recreational uses (CCME, 2001)

| Rank	WQI value	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment, conditions very close to natural or pristine level
Very Good	89-94	Water quality is protected with a slight present of threat or impairment, conditions very close to natural or pristine level
Good	80-88	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels
Fair	65-79	Water quality is protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Marginal	45-64	Water quality frequently threatened or impaired; conditions often depart from natural or desirable levels
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels
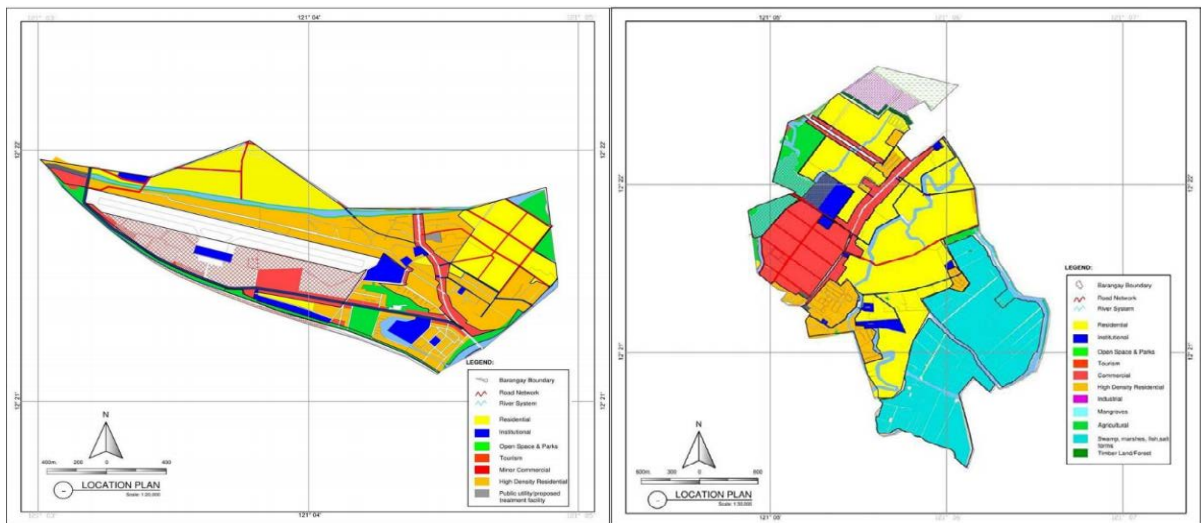
Fig. 2: General land use map of (a) San Roque (b) Labangan Poblacion (LGU San Jose, 2017)

RESULTS AND DISCUSSION

Existing environmental conditions and processes

In general, the land use pattern in San Roque is mostly covered with high-density residential: residential and minor commercial areas. Most of the commercial areas are found along the coast of Aroma Beach and San Jose Airport. The coastal barangay of San Roque is located just a kilometer away from the town of San Jose along the Pandurucan River separating it from the town (Fig. 2). The mode of transportation is mostly thru tricycles that can roam around the town via cemented roads. On the Eastern part of the area is the town proper of San Jose and Bubog: North (LGU San Jose, 2017).

The barangay has a total land area of 335.35 hectares (ha) with 15, 749 populations in 2020. The population growth rate is 1.46% and crude death rate of 4.7% in 2020. 47% of the population belongs to the age group of 15-44 years old; 15% for 45-64 years old; 11% for 10-14 years old and 5-9 years old; 4% for 65 and above; and 2% for 0-11 months. The number of households in the barangay is 3, 610 where 936 households have access to Level I and 1,577 households have Level III water system and the rest from doubtful sources. Also, only 2, 291 of the total household have provision for sanitary toilets (LGU San Jose, 2020). Labangan Poblacion has a total land area of 718.33 hectares mostly covered by residential, swamps, marshes and fish/salt farms, and high-density residential and commercial areas.

Commercial areas include educational institutions, government, and private offices, cockpit, and business establishments. The inland barangay is also a kilometer away from the town proper of San Jose. The barangay is bounded by agricultural barangays at the south; the town of San Jose at the north; Bagong Sikat at the east and the municipality of Magsaysay at the west. Barangay Labangan Poblacion has a total population of 9,744 in 2020. The population growth rate is 1.68% and crude death rate of 3.2% in 2020. 47% of the population belongs to the age group of 15-44 years old; 16% for 45-59 years old; 10% for 10-14 years old and 5-9 years old; 9% for 60 and above; 7% for 1-4 years old; and 2% for 0-11 months. The number of households in the barangay is 2,397 where 622 households have access to Level I, 1,047 households have Level III water systems and the remaining have doubtful sources. Also, only 1,522 of the total household have provision for complete basic sanitation facilities (LGU San Jose, 2020).

Water supply and water use

From the survey conducted to 138 households and 153 households in Brgy. San Roque and Labangan, the general water use is primarily for domestic purposes. 82% of the respondents showed that the major water source is being supplied by the Prime Waters while 18% uses deep wells dug in their backyard. Prime Waters is the only identified water service provider in the municipality of San Jose that uses one deep well and 15 shallow wells (16 pumping houses) as its water sources with one reservoir situated at Brgy. Labangan and has 500 cum capacity. The pumping house located at the municipal hall of San Jose supplies water in Barangays 6, 7, 8, Pag-asa, and Caminawit supported by another pumping house in Doña Consuelo Subdivision. The pumping house is located in Brgy. Bagong Sikat supplies water for the barangays and San Roque area. The distribution line is mainly composed of 150mm PVC, 100mm PVC, and 75 mm PVC. The water supply is treated using chlorination where the dosage of chlorine oxide depends on the capacity of each pump (LGU San Jose, 2020). Most of the households experience unreliable water supply and undesirable water quality. 89% of the respondents used drinking water from the refilling station as the majority complains about the water quality being compromised by the presence of corrosive particles and bad smell due to too much chlorine. The 11% fetched their drinking water from the well; stored in bottled; and the majority drank water directly without any treatment. However, 83 experienced diarrhea where 32 were taken to a health facility while the rest took home remedies.

Drainage pattern

Drainage pattern can also affect the river system as it determines contributing factors and possible sources of contamination. In general, drainage in San Jose is composed of curb type and steel grated box type. However, there are still some areas in the municipality that do not have a reliable drainage system. All existing curbs and gutters in the municipality drain water to the Pandurucan River. While those that are in the area of San Roque drain water in the Bubog River. Fig. 3 shows the drainage system in the study area.

Physical-chemical and E. coli results

Following the procedures for in situ and laboratory analysis, the following results were observed. Water samples consider the wet season and dry season from September 2019 to August 2020 (Table 3). While, Fig. 4 shows the measured concentrations of each sampling station.

Water temperature is one of the most important physical characteristics of aquatic systems as it affects the biological, physical, and chemical processes for plants and animals. As temperature increases, photosynthesis and other chemical and metabolic reactions increase providing adequate nutrients for aquatic life (FOEN, 2012). Measured water temperature in sampling sites ranges from 27.87°C to 33.8°C and is acceptable for all classes of water use and suitable for some fishes and aquatic life as the standards require 26-30ºC for recreational waters. Potential hydrogen or pH indicates the acidity or alkalinity of water with 6.5 to 8.5 as the ideal value. The measured pH in the sampling stations ranges from 7.29 to 7.89. Based on the standards, the values are good for aquatic plants like algae and some fishes. Dissolved oxygen reflects the amount of oxygen dissolved in an aqueous solution as affected by the velocity of water flow, prevailing climate, type and the number of water organisms, amount of water nutrients, and the presence of organic waste and vegetation in the water. DO
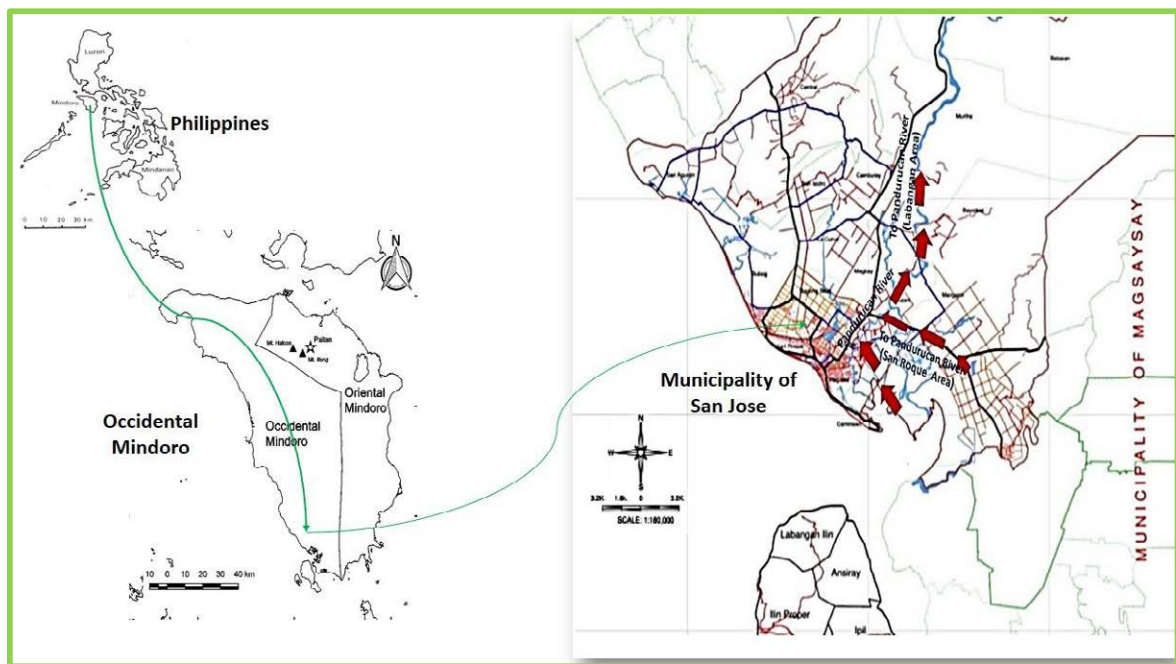
Fig. 3: Geographic location of the study area along with the existing drainage system in San Jose, Occidental Mindoro, Philippines

Table 3: Average concentrations of physical-chemical parameters

Physical-chemical parameters	Wet season				Dry season			
	1	2	3	4	1	2	3	4
Temperature (˚C)	27.87	28.53	29.49	30.61	29.64	32.04	33.3	33.8
pH (units)	7.29	7.57	7.49	7.89	7.44	7.41	7.34	7.42
Dissolved oxygen (mg/L)	6.39	3.92	3.35	3.61	6.35	2.82	2.88	3.34
Total dissolved oxygen (mg/L)	1311	1291	1355	1417	1386	1544	1562	1596
Total suspended solids (mg/L)	28.93	37.43	38.22	38.86	25.63	41.00	41.88	43.46
Phosphate (mg/L)	0.70	2.74	3.07	3.50	0.822	3.58	3.7	4.04
Oil and grease (mg/L)	1.22	2.56	2.72	3.17	1.36	2.94	2.94	4.14
Nitrate (mg/L)	0.44	2.58	2.86	3.11	0.53	3.39	3.47	3.26
Chloride (mg/L)	585.71	623.57	632.14	662.86	744.00	760.00	728.00	714.00
E. coli (MPN/100 mL)	234.71	414.86	442.86	306.57	201.80	242.20	265.4	222.00

level below 5.0 mg/L compromises aquatic life and significantly indicates poor water quality (Liu *et al.*, 2009; Li and Bishop, 2004). Measured DO in stations 2, 3, and 4 showed higher values and beyond the allowable limit. Lower DO in the sampling station is manifested by limited aquatic life with only spire snail shells and other small crustaceans are present. While DOs measured in station 1 were higher than 5.0 mg/L indicating healthy water as fishes and other crustaceans are observed in the site. Suspended solids containing much organic matter may cause

putrefaction and consequently lacks dissolved oxygen. The Total suspended solids found in water may include particles of clay, silt, decaying plant and animals, wastes, and sewage caused by water turbidity, high flow rate, and velocity of runoff. Based on the water quality criteria, TSS should not exceed 30 mg/L. The measured TSS on the sampling stations except Station 1 was higher during November and December 2019. TSS tends to increase during wet seasons and decreases during dry months. While Total dissolved solids (TDS) measures the inorganic
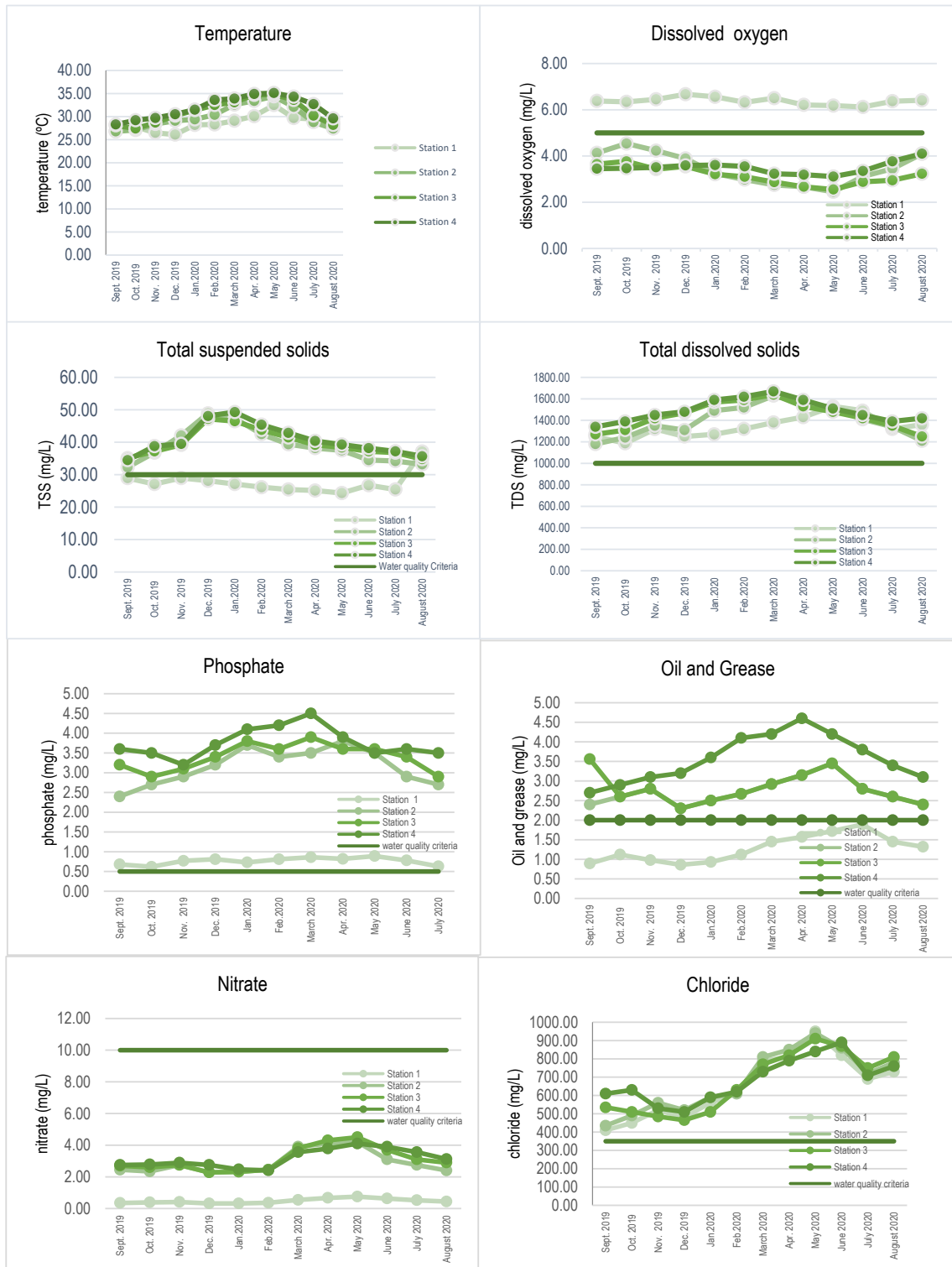
Fig. 4: Measured concentrations of physical –chemical water quality parameters in all stations
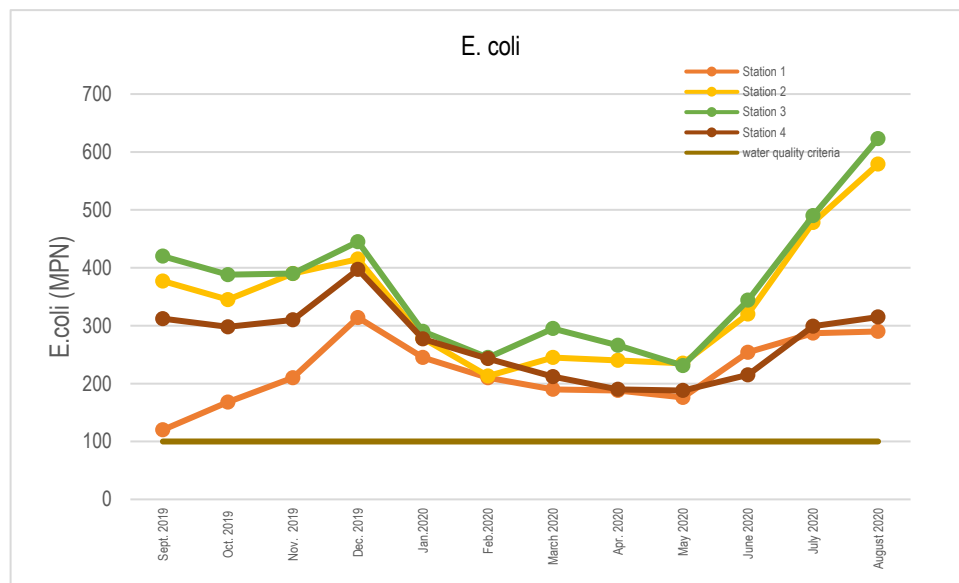
Fig. 5: Measured E. coli in the four sampling stations

salts like calcium, magnesium, and chloride dissolved in water (Bodzin, 2004). TDS affects the taste of water (WHO, 2003), and measured values must not exceed 1000 mg/L to meet the water quality criteria (DENR-EMB, 2016). The measured TSS ranges between 28.93 to 38.86 mg/L during the dry season and 25.63 to 43.46 mg/L during the wet season with only water from station 1 conforms to the water quality criteria. While the measured TDS in all stations exceed the allowable limits with higher values observed during the dry seasons. Higher phosphate can be dangerous to marine organisms causing tremendous development on aquatic bloom and lessen the amount of light in the water thus, decreasing the amount of dissolved oxygen. When algae grow quickly, they die quickly contributing to the organic waste and decomposition of bacteria. The acceptable range of phosphate concentration in river water is 0.50 mg/L (DENR-EMB, 2016). The measured phosphate in four sampling stations ranges between 0.70 to 3.5 mg/L during the wet months and 0.82 to 4.04 mg/L during the dry months. The algae are commonly observed in the river banks and with higher phosphate concentrations, limited aquatic life is observed and deprived of sufficient oxygen (Khan *et al.,* 2006). Oil and grease can damage the aquatic environment and interfere

with aerobic and anaerobic biological processes. Measured concentrations for oil and grease were higher during the dry months as it ranges between 1.08 to 3.5 mg/L with water samples from Station 1 conforms to the acceptable limit of 2 mg/L. Oil films are also observed in water surfaces of stations, 2, 3, and 4 indicating the presence of contaminants (Moslem *et al.,* 2013) comprising the usability of the river system (US EPA, 1999). The allowable limit for nitrates concentration is 10 mg/L and an excessive amount may lead to algal bloom causing depletion of oxygen affecting the aquatic life (DENR-EMB, 2016). The measured concentrations of nitrate in the four sampling stations do not exceed the allowable limit but higher values were measured during March and May where agricultural activities are dominant in the surrounding environment as runoff from nitrogen fertilizers, domestic wastewater, human and animal waste are commonly observed (Wright *et al.,* 2004). Chloride is a measure of sodium and potassium content of the water samples and must be less than 350 mg/L for freshwater (DENR-EMB, 2016). High chloride in the water body indicates saltwater intrusion. All water samples in all stations exceed the normal value for the freshwater significantly describing that the water is salty.

E. coli is a common bio-indicator of water

Table 4: Computed WQI in each station

Stations	Computed WQI	Rank	Description
Station 1	60.06366	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Station 2	35.20767	Poor	
Station 3	30.64781	Poor	Water quality is almost always threatened or impaired;
Station 4	30.17662	Poor	conditions usually depart from natural or desirable levels.
Average	39.023945	Poor	

pollution and indicator of contamination, diseases, and unsafe drinking (Ram *et al.*, 2008; Yogendra *et al.*, 2008). The E. coli is measured by the Most Probable Number per 100 mL of water sample (MPN/100 mL) and must not exceed 100MPN/100 mL for recreational uses (DENR-EMB, 2016). Results of the microbial analysis show the presence of E. coli in all water samples (Fig. 5). Higher values were measured in Station 3 particularly from November to December 2019 and from June to August 2020.

Following the mathematical framework of CCME in assessing the ambient water quality, the computed water quality index on the four sampling stations generally described that the water samples do not meet the allowable requirement of water quality. The average WQI described that the water is poor and always threatened and compromised by the surrounding environment (Table 4).

Statistical analyses

One-way ANOVA was employed to determine the significant relationship of ten water quality parameters measured in four sampling stations. The result shows a p-value of 0.232 and 0.09659 for pH and chloride. The measured concentrations on other parameters were generally similar. Stations 2 and 4 have the highest value of pH and chloride concentrations. Station 2 generally receives the pH concentrations from Station 1 as it is surrounded by salt farms and other industrial effluents. As water flow in station 2 is slower, much of the concentrations settled in the site. Station 4 is located where seawater freely intrudes the site that contributed to the increase chloride concentrations. Since the monitoring covered the wet and dry seasons, significant differences on the variation of seasons to the measured concentrations were determined using one-way ANOVA. January to May was considered as dry seasons as no rainfall was measured, while June to December was considered

as wet months. Results show that pH, dissolved oxygen, total suspended solids, phosphate, oil and grease, nitrate, and E. coli vary significantly with seasons with p-values of 0.259, 0.682, 0.669, 0.603, 0.569, 0.672, and 0.0587, respectively. Measured concentrations for pH, DO and E. coli were higher during the wet seasons which can be attributed to surface runoff, septic tanks overflow, and flooding during the rainy seasons. TSS, phosphate, oil and grease, and nitrate were higher during the dry seasons and can attributed to the increased in agricultural and economic activities, farming and fishing, and agricultural wastes that were intercepted in the river system.

Proposed interventions and management plan strategies

The economic, industrial, and agricultural activities contributed to the measured concentrations of water quality parameters in Pandurucan River. The poor management of river water compromises the quality of water that limits the available benefits for San Joseños. The lack of a municipal sewage system that should collect the solid and wastewater from septic tanks; the drainage system that directly goes into the river; the indiscriminate waste disposal of the surrounding community; and the lack of concrete policies to safeguard the river are the major contributing factors that lead to the deterioration of the Pandurucan River. Reviving the river will become possible if policymakers, water managers and the community will work hand in hand on minimizing the sources of pollution. Provision for sewerage system and improvement of the drainage system must be initially considered by the local government unit to provide a proper system for the collection and disposal of garbage and wastes. Encouraging the community to practice proper garbage segregation and disposal and build septic tanks will help lessen the indiscriminate disposal

of garbage into bodies of water. Cleaning activities on river beds and banks will help improve the river's flow pattern and velocity. More importantly, implementation of policies and ordinances that will promote preservation and restoration of the river water to enlighten the community to become aware, participate, and support all intervention measures.

CONCLUSION

The water quality management plan of Pandurucan River presents the physical-chemical and microbiological characteristics of the water quality standards of DAO 2016-08. From the four sampling stations, grab water samples were taken and in-situ and laboratory tests were performed to obtain the desired objectives. Four of nine physical-chemical parameters failed to meet the water quality standards: phosphate measured ranges between 2.40-4.50 mg/L exceeding the allowable 0.50mg/L; oil and grease measured were found to exceed the standards of 2 mg/L with measured values of 2.40-4.60 mg/L in stations 2, 3 and 4; while measured chloride in all stations exceeds the freshwater requirement of 250mg/L; and the measured TSS in stations 2, 3 and 4 ranging from 32.30 to 49.3 mg/L exceeds the 30mg/L standards. The detected E. coli in all sampling stations indicates the presence of contaminants in the river. The results show that river water is not safe for recreational purposes like swimming and bathing as accidental intakes and skin contact on contaminated water can cause health problems. The garbage collection and disposal of the surrounding community contributed to the sources of pollution in the river as most of the households do not have reliable sanitation facilities. The lack of a dependable drainage system in the municipality also contributed to the source of contaminants as collected water in the curb and box-type drainages drain directly in the river. These practices and activities contribute to the Poor water quality index computed in the study area. As the local government unit aims to rehabilitate the Pandurucan River to become a tourist destination, this study can serve as a framework in the water quality management plan and provide a scientific basis to establish policies and guidelines in the surrounding community. The interventions, management, and rehabilitation strategies must be first initiated by the policymakers and should involve the stakeholders, water managers, and the community in improving and protecting the water quality. As an initial undertakings in the study area; the water quality parameters; calculated WQI, sources of contaminants determined in this study will serve as input data on the study related to the fate and transport of bacteria and calculate the associated heath risk if water is ingested or accidentally taken.

AUTHOR CONTRIBUTIONS

M. Enriquez performed the experimental design, analyzed and interpreted the data, prepared the manuscript text and manuscript revision. R. Tanhueco checked the experimental design, interpretation of data, manuscript text and manuscript revision.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

PUBLISHER'S NOTE

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ABBREVIATIONS

%	Percent
ANOVA	Analysis of variance
Brgy.	Barangay
CCME	Canadian Council of Ministers and Environment
ºC	Degree Celsius
DAO	Department of Environment and Natural Resources Administrative Order
DENR-EMB	Department of Environment and Natural Resources- Environmental Management Bureau
DO	Dissolved oxygen
E. coli	Escherichia coli
ENRO	Environment and Natural Resources Office
Eq.	Equation
Fig.	Figure
ha	Hectare
LGU	Local Government Unit
mg/L	Milligrams per liter
mL	Milliliter
mm	Millimeter
MPN	Most Probable Number
OMSC	Occidental Mindoro State College
PAG-ASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
pH	Potential Hydrogen
p-value	Probability value
PVC	Polyvinyl chloride
RA 9275	Republic Act 9275
TDS	Total dissolved solids
TSS	Total suspended solids
WHO	World Health Organization
WQA	Water Quality Analysis
WQI	Water Quality Index
WQMP	Water Quality Management Plan
US EPA	United States Environmental Protection Agency

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